Final Precursor Analysis

Accident Sequence Precursor Program -- Office of Nuclear Regulatory Research

Grand Gulf Unit 1	Automatic Reactor SCRAM Due To Loss of Offsite Power With Condenser Vacuum Pump Inoperable and Subsequent Failure of Instrument Air	
Event Date 4/24/2003	LER: 416/03-002	CCDP[1] = 1.3×10^{-6}

August 22, 2005

Event Summary:

On April 14, 2003, *ENTERGY Mississippi* removed 500 kV Breaker J5204 (See Figure 1) from service in the switchyard at Grand Gulf Nuclear Station by opening disconnects J5203 and J5205 in order to repair an internal gas leak (See Figure 1). On the morning of April 24, 2003, work was continuing on Breaker J5204 when high winds in the switchyard caused Disconnect Switch J5205 to close, creating a line-to-ground fault, which isolated all incoming 500 kV power to Service Transformer 21 (ST21). Coincident with this, failures in the *ENTERGY Mississippi* carrier transmission fault relaying system caused both 500 kV power sources from the Baxter-Wilson Station and the Franklin Station switchyards to be isolated from the Grand Gulf Nuclear Station switchyard. The Grand Gulf generator temporarily remained on the 500 kV east bus powering ST11.

Because of this 500 kV electrical grid transient, the Grand Gulf Nuclear Station turbine generator control system sensed a full load rejection and responded by initiating a turbine control valve fast closure and automatic reactor trip. (References 1,2) All control rods inserted as designed. Loss of transformer ST21 resulted in a bus undervoltage on the Division I, II and III ESF busses that resulted in the start of the Division I, II and III emergency diesel generators. Reactor water level 2 was reached, MSIVs closed (due to loss of the two RPS buses), and the High Pressure Core Spray (HPCS) and Reactor Core Isolation Cooling (RCIC) systems started as designed. Operators stabilized and maintained reactor pressure vessel (RPV) water level according to procedures. Reactor pressure was maintained by the proper cycling of the Safety/Relief Valves (S/RVs). Approximately a half hour into the event, suppression pool cooling was initiated using the Residual Heat Removal (RHR) Systems. A detailed sequence of events is provided in Appendix A.

Essential AC electrical buses were properly supplied throughout the duration of the event by the operation of the emergency diesel generators. Had any of the emergency buses become de-energized due to the failure of a diesel, the buses could be transferred back to offsite sources.

[1]For the initiating event assessment, the parameter of interest is the measure of the CCDP. This is the value obtained when calculating the probability of core damage for an initiating event with subsequent failure of one or more components following the initiating event. The value reported here is the mean value.

The transition of the plant to eventual cold shutdown was complicated by the loss of the Instrument Air System which required approximately 2 hours to restore. The Instrument Air System supports several systems credited in the plant emergency procedures for alternate emergency decay heat removal and containment cooling. These systems include: CRD flow (in the enhanced flow control mode), Fire Water makeup to the RPV, and Containment Venting for Containment Heat Removal. Had the normal operation of HPCS, RCIC, and RHR systems failed and the need to utilize alternate RPV makeup and containment cooling, these alternate measures would have been impacted until Instrument Air was restored. Firewater makeup to the RPV can be accomplished without Instrument Air by opening a motor operated bypass valve either remotely or via turning a handwheel.

Analysis Results

- **Conditional Core Damage Probability (CCDP)**

  This event was modeled as an initiating event loss of offsite power (LOOP) with complications caused by the additional loss of Instrument Air. The CCDP for this event was calculated as 1.0 $\times 10^{-6}$ (point estimate). An uncertainty analysis was performed to assess the effects of parameter uncertainties. The results are summarized below.

	CCDP		
	5%	**Mean**	**95%**
Grand Gulf Unit 1	**1.0 x 10^{-7}**	**1.3 x 10^{-6}**	**4.3 x 10^{-6}**

- **Dominant Sequences**

Appendix B provides the event tree models used in this analysis. The actual event sequence of the April 24, 2003 event is LOOP Sequence 1, shown in Figure B-1 of Appendix B. If additional system or component failures had occurred a core damage sequence could occur. There are five dominant accident sequences (See Table 1) which account for 79% of the total CCDP. All other accident sequences account for less than 6.5% of the total CCDP.

The most dominant accident sequence is LOOP Sequence 41-04 which accounts for 24% of the total CCDP. The important system and component failures in Sequence LOOP 41-04 (See Figures B-1, B-2 of Appendix B) are:

- Loss of Offsite Power occurs
- Automatic Reactor Trip occurs
- Emergency Power is supplied by the Diesel Generators
- S/RVs open and close to control RPV pressure and one fails to re-close
- High Pressure Core Spray is actuated
- Suppression Pool Cooling is attempted but fails
- Containment Spray Cooling is initiated
- Containment Venting fails due to Loss of Instrument Air

The next most dominant Sequence: LOOP 44-03-14 accounts for 18% of the total CCDP. The important system and component failures of Sequence LOOP 44-03-14 (See Figures B-1, B-3, and B-4 of Appendix B) are:

- Loss of Offsite Power occurs
- Automatic Reactor Trip occurs
- Emergency Power from the Diesel Generators fails
- Division III Emergency Power from the HPCS Diesel Generator is available
- High Pressure Core Spray is attempted but fails
- Operators successfully cross-tie the Division III Bus to other plant Buses
- S/RVs open and close to control RPV pressure without failure to re-close
- Reactor Core Isolation Cooling is actuated but fails
- Operators successfully carry out Emergency RPV Depressurization
- Low Pressure Coolant Injection is attempted but fails

The next most dominant Sequence: LOOP 40 accounts for 15% of the total CCDP. The important system and component failures of Sequence LOOP 40 (See Figure B-1 of Appendix B) are:

- Loss of Offsite Power occurs
- Automatic Reactor Trip occurs
- Emergency Power is supplied by the Diesel Generators
- S/RVs open and close to control RPV pressure without failing to re-close
- High Pressure Core Spray is actuated but fails
- Reactor Core Isolation Cooling is actuated but fails
- Manual Depressurization fails
- 2/2 CRD injection in high flow mode fails

The next most dominant Sequence: LOOP 05 accounts for 12% of the total CCDP. The important system and component failures of Sequence LOOP 05 (See Figure B-1 of Appendix B) are:

- Loss of Offsite Power occurs
- Automatic Reactor Trip occurs
- Emergency Power is supplied by the Diesel Generators
- S/RVs open and close to control RPV pressure without failing to re-close
- High Pressure Core Spray is actuated to provide RPV makeup
- Suppression Pool Cooling is attempted but fails
- Operators successfully carry out Emergency RPV Depressurization
- Containment Spray Cooling is attempted but fails
- Containment Venting fails due to Loss of Instrument Air

The next most dominant Sequence: LOOP 44-39 accounts for 10% of the total CCDP. The important system and component failures of Sequence LOOP 44-39 (See Figures B-1 and B-3 of Appendix B) are:

- Loss of Offsite Power occurs
- Automatic Reactor Trip occurs
- Emergency Power from the Diesel Generators fails
- Division III Emergency Power from the HPCS Diesel Generator fails
- S/RVs open and close to control RPV pressure without failing to re-close
- Reactor Core Isolation Cooling is attempted but fails

- **Results Tables**

- The conditional probabilities for the dominant sequences are shown in Table 1.
- The event tree sequence logic for the dominant sequences are presented in Table 2a.
- Table 2b defines the nomenclature used in Table 2a.
- The most important cut sets for the dominant sequences are listed in Table 3a and 3b.
- Definitions and probabilities for modified or dominant basic events are provided in Table 4.

Modeling Assumptions:

- **Analysis Type**

The actual event was a loss of onsite electric power (OEP) that occurred with two sources of off-site power available and that could be reconnected if necessary. The event was modeled in this analysis as a loss of offsite power initiating event (IE-LOOP) using the Grand Gulf Revision 3.10 Standardized Plant Analysis Risk (SPAR) Model (Reference 4). The probability of IE-LOOP was set to 1.0. The probabilities of the other initiating events were set to 0.0. The analyzed LOOP duration is equivalent to the actual event. The LOOP initiating event and its duration are therefore considered key boundary conditions for this analysis.

Equipment and operator actions that were successful during the actual event are assumed to perform at their normal failure probability values. Equipment and operator actions that failed during the event are failed (set to TRUE) in the analysis.

LOOP recovery basic events that occur prior to offsite power being available are set TRUE (failed). These events can not be successful since the know duration of the offsite power event is greater than the time available for recovery action. LOOP recovery basic events that occur after offsite power is available are set consistent with the human error likelihood of re-energizing the ESF buses. This analysis approach of replacing the statistically based non-recovery curves contained in the SPAR model with specific human actions which follows the approach of analyzing a LOOP event of known duration. Since the LOOP duration is known, then the status of power to the switchyard is known at any given time. However, the normal value for the actions to re-energize the ESF buses given switchyard power is available needs to be determined. The human error likelihood is determined using the SPAR-H methodology (Reference 5). Since the Grand Gulf event was a momentary LOOP, then there are no LOOP recovery events set to true.

The emergency diesel generator mission run times have been adjusted consistent with the time it took to re-energize the various ESF buses from the offsite power following the event.

Other changes to model the event are described below.

- **Unique Design Features**

  Grand Gulf is a standard General Electric BWR-6, with a Mark III containment.

- **Modeling Assumptions Summary**

  Key modeling assumptions. The key modeling assumption are listed below and discussed in detail in the following sections. These assumptions are important contributors to the overall risk.

  - **Offsite 500kV Power was lost for approximately 74 seconds.** Following the inadvertant closure of the disconnect, an undervoltage condition of Division II and III ESF buses cause the autostart of the Division II and III emergency diesel generators. Failures in the carrier transmission fault relaying system caused both normal 500kV power sources from the Baxter-Wilson Station and Franklin Station switchyards to be isolated from the Grand Gulf switchyard. Because the of this 500kV power grid transient, the Grand Gulf turbine generator controls sensed a load rejection resulting in an automatic reactor scram. Approximately 74 seconds later, the main generator output breaker opened resulting in a loss of 500kV to the Division I ESF bus. The Division I emergency diesel generator then autostarted. At about the same time, the 500kV Franklin and Baxter-Wilson line feeder breakers closed and restored power to the Grand Gulf Nuclear Station (GGNS) switchyard (Reference 6).

  - **The Port Gibson 115kV line was available throughout the event.** GGNS is supplied with AC power from the 500kV switchyard and the 115kV (Port Gibson) offsite circuit. From the switchyard, AC voltage is stepped down to 34.5kV through two service transformers that supply two ESF transformers and eight balance of plant (BOP) transformers. The 115kV offsite circuit feeds another ESF transformer with 4160V output voltage (References 1, 2). This 115kV line available for offsite power recovery at all times during this event and the operators were found to adequately trained on connecting this power supply in a proper and safe manner (Reference 6).

  - **The GGNS emergency diesel generators ran for the following mission times - Division I: 6.2 hours, Division II: 5.8 hours, and Division III: 5.075 hours** (Reference 1). Diesel generator fail to run and common cause failure to run probabilities were adjusted to reflect the run time of the first diesel to be secured, namely 5.07 hours.

  - **Instrument Air system became totally unavailable at the time of loss of offsite power and was not recovered until an instrument air compressor was successfuly restarted at two hours into the event.** During the actual loss of offsite power event, the running Instrument Air and Service Air System compressors shutdown as designed. Operators were unable to remotely restart the air compressors due to a loss of control air. The Unit 1 Instrument Air compressor was manually started about 20 minutes into the event (Reference 1) but was ineffective in restoring the air header and was shutdown several minutes later. Approximately two hours into the event, operators were successful in starting the Unit 2 Instrument Air compressor and used it to restore the air header pressure.

- **The CRD pumps and Containment Vent valves, both credited for long term heat removal, depend on the Instrument Air System.** The Grand Gulf IPE (Table 3.2-3 of Reference) illustrates that the Instrument Air System supports all of the following systems:
  (a) CRD pump enhanced flow control (alternate RPV makeup),
  (b) Opening valves to allow Fire Water Injection (alternate RPV makeup),
  (c) Long term makeup to the dedicated bottled air supply for the S/RVs[2],
  (d) Opening, modulation of Feedwater flow control valves (alternate RPV makeup),
  (e) Opening Containment vent valves (alternate decay heat removal),
  (f) Plant Service Water which supports Instrument Air compressor cooling,
  (g) Modulation of the chilled water system flow control.
  (h) Re-opening of closed Main Steam Isolation Valves to restore heat removal by Main Condenser
  In the SPAR loss of offsite power event sequence analysis, only items (a) and (e) are modeled in the current SPAR event trees. Modeling the support dependencies of the other systems would only be necessary in non-LOOP transient events.

- **There was no possibility to recover the main condenser unit as an alternate decay heat removal system.** At the time the April 24th event, Reference 2 noted that the main condenser mechanical vacuum pump system was tagged out for maintenance. This implies any temporary interruption in loss of main steam flow (such as via the closure of the MSIVs) would incapacitate the steam jet air ejectors that remove non-condensible gasses. Without a mechanical vacuum pump, this combination results in a loss of condenser vacuum and inability to use the use the main condenser as an alternate decay heat removal. *The current SPAR loss of offsite power event sequence models do not credit recovery of the main condenser after re-opening the MSIVs.*

- **Fault Tree Modifications**

Addition of a basic event AIR-XHE-NOREC-2HR to the Control Rod Drive (CR1) and Containment Venting of the Suppression Pool (CVS) fault trees for the non-recovery of Instrument Air. Two changes were made to the Grand Gulf 1 SPAR Model Fault Trees:

(1) *Modifications to the CR1 Fault Tree to Account for Non-recovery of Instrument Air*

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[2]Compressed air to operate the Safety/Relief valves was available throughout the event from dedicated bottles which are hold a sufficient reserve to allow multiple cycles.

The base case CR1 fault tree was modified by the addition of a basic event describing the non-recovery of Instrument Air over the long term (~ 2 hours) which similarly prevents modulating the CRD flow control valves to their full open position. The specific logic modifications are shown in Figure C-1 in Appendix C. The fault probability is derived in the HRA in Appendix D.

(2) *Modifications to the CVS Fault Tree to Account for Non-recovery of Instrument Air*
The base case CVS fault tree was modified by the addition of a basic event describing the non-recovery of Instrument Air over the long term (~ 2 hours) which similarly prevents opening the containment venting valves to their full open position. The specific logic modifications are shown in Figure C-2 in Appendix C. The fault probability is derived in the HRA in Appendix D.

- **Basic Event Probability Changes** Table 4 provides all the basic events that were modified to reflect the best estimate of the conditions during the event. The basis for these changes are provided below.

Operators fail to recover offsite power in 30 minutes (OEP-XHE-XL-NR30M) and within one hour (OEP-XHE-XL-NR01H). These basic event probabilities were changed to 2.0×10^{-2} reflecting the fact that offsite power was available and all that was required was to properly execute the procedure to reconnect. Short term offsite power recovery is considered in the situation of a Station Blackout with a stuck open S/RV. The bases for this number is formally derived in the HRA in Appendix D and considers the fact that required time to carry out the recovery was on the order of the available time.

Operators fail to recover offsite power at 2 hours, 4 hours, 8 hours and 10 hours (OEP-XHE-XL-NR02H, OEP-XHE-XL-NR04H, OEP-XHE-XL-NR08H, OEP-XHE-XL-NR10H). These basic event probabilities were all changed to 2.0×10^{-4} reflecting the fact that offsite power was available and all that was required was to properly execute the procedure to reconnect. Longer term offsite power recovery is credited for sequences where suppression cooling is required.The bases for this number is formally derived in the HRA in Appendix D and considers the fact that required time to carry out the recovery was significantly less than the available time.

Modifications to diesel generator failure to run probability to reflect actual diesel run times during the event. The diesel generator failure to run probability in the base case SPAR model (Reference 4) is based on a compound event which includes portions dealing with short term failure to run (one hour or less) and a longer term failure model which uses a different failure rate. The base case model assumes a 24 hour run time mission. The base events involved are: **EPS-DGN-FR-DGA, EPS-DGN-FR-DGB,** and **EPS-DGN-FR-DGC.** These compound base events are in turn composed of short term and longer term basic elements: **ZTN-DGN-FR-E,** and **ZTN-DGN-FR-L** which are each calculated based on $Pr(t) = 1 - \exp(-\lambda t)$ using different hourly failure rates.

Where: $\lambda_e = 3.0 \times 10^{-3}\ hr^{-1}$ (short term failure rate) and λ_l = 8.4 x 10-4 hr^{-1} (longer term failure rate)

The total diesel failure to run probability becomes for 5.07 hour mission time:

$$Pr = 1 - \exp(-\lambda_e \times 1hr) + 1 - \exp(-\lambda_l \times (5.07 - 1hr)) = 6.25 \times 10^{-3}$$

The **EPS-DGN-FR-DGA, EPS-DGN-FR-DGB, and EPS-DGN-FR-DGC** values were changed to the value noted above as shown in Table 4. This change results in a reduction in the failure to run probabilities for all three diesels.

- **SPAR Model Corrections**

The existing SPAR Model LOOP event tree assumptions for scenarios where emergency power is available, there are no open S/RVs, and some form of RPV makeup has been continuously maintained do not consider the availability of Shutdown Cooling and are excessively pessimistic. This is an inconsistency in modeling assumptions for equivalent modeling for general plant transients. To correct this model assumption, the recovery model for the LOOP event tree was modified by addition of the following recovery rule:

```
| Long-term recovery of SDC given initial success of injection.
if system(/SRV)
*(system(/HCS)+system(/RCI)+system(/CRD)+system(/CDS)+system(/LCS)+
system(/LCI)+system(/VA)) * (system(SD1) + system(SDC)) then
  AddEvent = SDC-LTERM-NOREC;
```

This recovery rule is identical to that utilized for general plant transients.

- **Sensitivity Analyses**

Sensitivity analyses were performed to determine the effects of data and modeling uncertainties on the CCDP = 1.0×10^{-6} point estimate result which is treated as the base case. To assess data uncertainties, an Importance Analysis using Fussel-Vesely and Risk Increase Ratio importance measures was conducted to identify the most sensitive parameters.

The following table provides the results of the sensitivity analyses and how the resultant CCDP changed from the base case value of 1.0×10^{-6} as a result of single parameter changes.

Sensitivity Study	Modification	CCDP[1]
1	**RCI-XHE-XO-ERROR** (Operator fails to start or control RCIC) failure probability increased by x 5.0	1.8×10^{-6}
2	**SSW-MDP-TM-TRNA** (Service Water Pump Test and Maintenance) unavailability increased by x 5.0	2.0×10^{-6}
3	**ADS-XHE-XM-MDEPR** (Operator fails to Start or Control RHR) failure probability increased by x 5.0	1.7×10^{-6}
4	**OEP-XHE-XL-NR08H** (Operator fails to recover onsite electric power within 8 hours) failure probability increased by x 5.0	1.3×10^{-6}
5	**AIR-XHE-NOREC-2HR** (Operators fail to recover Instrument Air within 2 Hours) failure probability increased by x 5.0	1.5×10^{-6}

Note 1: CCDP sensitivity study calculations are based on point estimate values.

The conclusion from these sensitivity studies is that relatively large changes in the most sensitive base event probability values results in effects that are within the 90% bounds.

References:

1. Grand Gulf Nuclear Station, Unit 1, LER: 416/03-002, “Reactor Scram Due to a Partial Loss of Offsite Power”, issued June 23, 2003. ML032790367

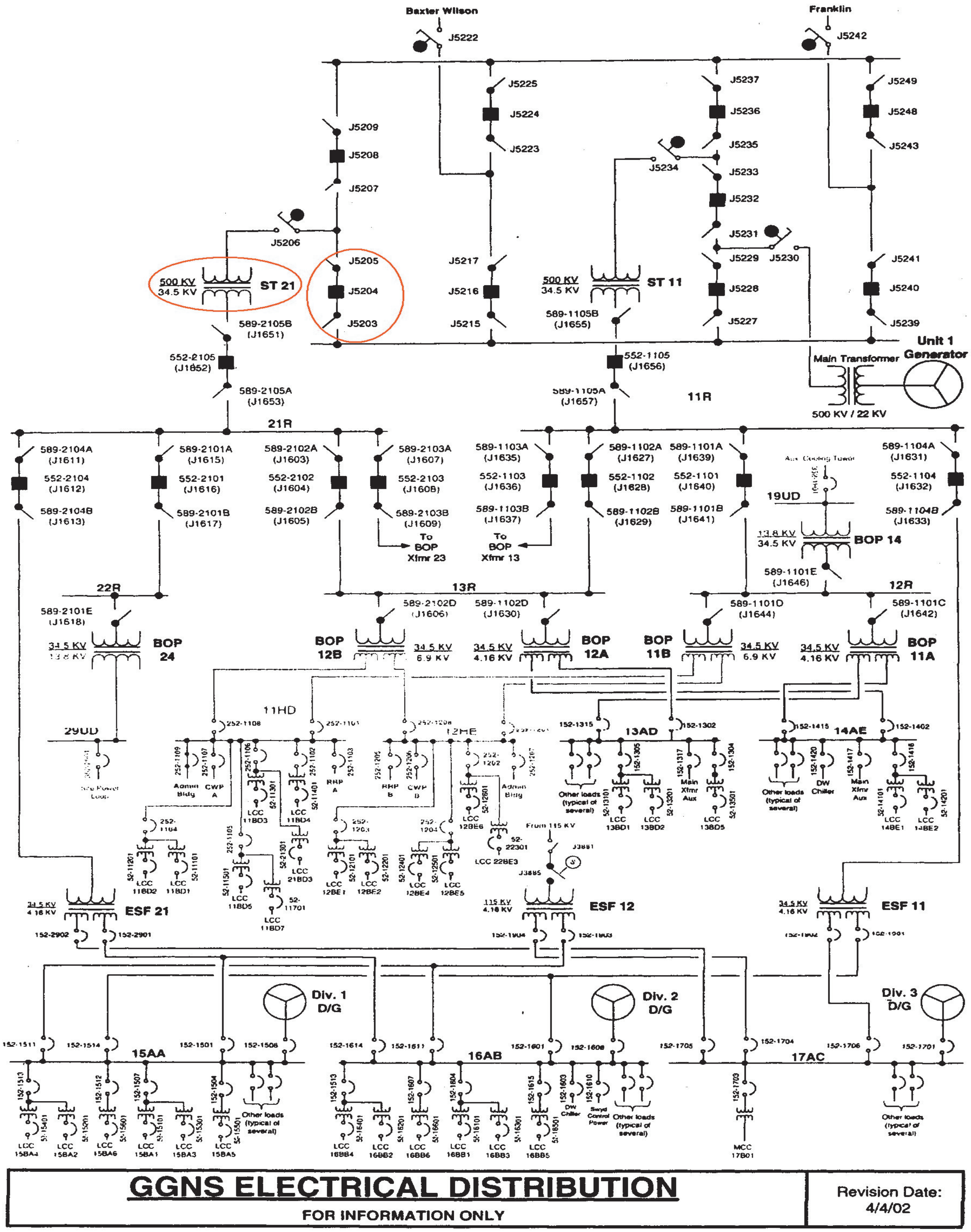
2. Inspection Report IR: 50-416/2003-02. ML032090437

3. “Risk Assessment for Reactor Trip with Loss of Offsite Power and Loss of Instrument Air”, Memo from D.P. Loveless(NRC Region IV) to W.D. Johnson, issued April 30, 2003.

4. Idaho National Engineering and Environmental Laboratory, “Standardized Plant Analysis Risk Model for Grand Gulf 1 (ASP BWR C),” Revision 3.10, December 10, 2004.

5. Grand Gulf Nuclear Station, Individual Plant Evaluation Summary Report, December 1992.

6. “The SPAR-H Human Reliability Analysis Method,” INEEL/EXT-02-01307, May 30, 2004.



Baxter Wilson
J5222
Franklin
J5242
J5225
J5224
J5223
J5237
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J5235
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J5232
J5231
J5229
J5230
J5228
J5227
J5249
J5248
J5243
J5241
J5240
J5239
J5209
J5208
J5207
J5206
J5205
J5204
J5203
J5217
J5216
J5215
500 KV
34.5 KV
ST 21
ST 11
589-2105B
(J1651)
552-2105
(J1652)
589-2105A
(J1653)
589-1105B
(J1655)
552-1105
(J1656)
(J1657)
11R
Unit 1
Generator
Main Transformer
500 KV / 22 KV
21R
589-2104A
(J1611)
552-2104
(J1612)
589-2104B
(J1613)
589-2101A
(J1615)
552-2101
(J1616)
589-2101B
(J1617)
589-2102A
(J1603)
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(J1604)
589-2102B
(J1605)
589-2103A
(J1607)
552-2103
(J1608)
589-2103B
(J1609)
To BOP Xfmr 23
589-1103A
(J1635)
552-1103
(J1636)
589-1103B
(J1637)
To BOP Xfmr 13
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589-1101B
(J1641)
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(J1631)
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(J1632)
589-1104B
(J1633)
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13.8 KV
34.5 KV
BOP 14
589-1101E
(J1646)
22R
13R
12R
589-2101E
(J1618)
589-2102D
(J1606)
589-1102D
(J1630)
589-1101D
(J1644)
589-1101C
(J1642)
BOP 24
BOP 12B
34.5 KV
6.9 KV
4.16 KV
BOP 12A
BOP 11B
BOP 11A
11HD
12HE
13AD
14AE
29UD
ESF 21
ESF 12
ESF 11
115 KV
4.16 KV
152-2902
152-2901
Div. 1 D/G
Div. 2 D/G
Div. 3 D/G
15AA
16AB
17AC
GGNS ELECTRICAL DISTRIBUTION
FOR INFORMATION ONLY
Revision Date:
4/4/02

Figure 1

Table 1. Conditional core damage probabilities of dominating sequences.

Event tree name	Sequence no.	CCDP[1]	Contribution
LOOP	41-04	2.4×10^{-7}	24.6%
LOOP	44-03-14	1.8×10^{-7}	18%
LOOP	40	1.5×10^{-7}	15%
LOOP	05	1.2×10^{-7}	12%
LOOP	44-39	1.0×10^{-7}	10%
Total (all sequences)[2]		1.0×10^{-6}	100 %

1. Values are point estimates.
2. Total CCDP includes all sequences (including those not shown in this table).

Table 2a. Event tree sequence logic for dominant sequence.

Event tree name	Sequence no.	Logic ("/" denotes success; see Table 2b for top event names)
LOOP	41-04	/RPS /EPS P1 /HCS SPC CSS CVS
LOOP	44-03-14	/RPS EPS /B1 HCS /DGX /SRV RC1 /DEP LCI1
LOOP	40	/RPS /EPS /SRV HCS RCI DEP CRD
LOOP	05	/RPS /EPS /SRV /HCS SPC /DEP SDC CSS CVS
LOOP	44-39	/RPS EPS B1 P1 RCI

Table 2b. Definitions of top events listed in Table 2a.

Top Event	Definition
RPS	REACTOR SHUTDOWN FAILS
EPS	LOSS OF ONSITE EMERGENCY POWER
SRV	ONE OR MORE SRVS FAIL TO CLOSE
P1	ONE SRV FAILS TO CLOSE
B1	DIVISION III POWER AVAILABLE
HCS	HPCS FAILS TO PROVIDE SUFFICIENT FLOW TO RX VESSEL
SPC	SUPPRESSION POOL COOLING MODE OF RHR FAILS
DGX	DIVISION III POWER CROSS-TIE
RCI	REACTOR CORE ISOLATION COOLING
RC1	REACTOR CORE ISOLATION COOLING
DEP	MANUAL DEPRESSURIZATION FAILS
SDC	SHUTDOWN COOLING MODE OF RHR IS UNAVAILABLE
CSS	CONTAINMENT SPRAY MODE OF RHR FAILS
LCI1	LOW PRESSURE COOLANT INJECTION (ONE TRAIN)
CRD	CONTROL ROD DRIVE PUMP INJECTION (2 PUMPS)
CVS	CONTAINMENT (SUPPRESSION POOL) VENTING

Table 3a. Conditional cut sets for the dominant sequences.

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)	
Event Tree: LOOP Sequence 41-04			
3.1E-008	12.94	PPR-SRV-OO-1VLV AIR-XHE-NOREC-2HR	RHR-XHE-XM-ERROR
1.6E-008	6.47	PPR-SRV-OO-1VLV CVS-XHE-XM-VENT	RHR-XHE-XM-ERROR
1.4E-008	5.82	CVS-AOV-CC-AV36 RHR-XHE-XM-ERROR	PPR-SRV-OO-1VLV
1.4E-008	5.82	CVS-AOV-CC-AV34 RHR-XHE-XM-ERROR	PPR-SRV-OO-1VLV
1.4E-008	5.82	CVS-AOV-CC-AV35 RHR-XHE-XM-ERROR	PPR-SRV-OO-1VLV
1.4E-008	5.82	CVS-AOV-CC-AV37 RHR-XHE-XM-ERROR	PPR-SRV-OO-1VLV
3.4E-009	1.40	PPR-SRV-OO-1VLV AIR-XHE-NOREC-2HR	RHR-MDP-CF-START
2.46×10^{-7}	**24.6%**	**Total (all cutsets)[1]**	

1. Total Importance includes all cutsets (including those not shown in this table).

Table 3a. (Continued) Conditional cut sets for the dominant sequences.

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)	
Event Tree: LOOP Sequence 44-03-14			
1.8E-008	10.07	RCI-XHE-XO-ERROR EPS-DGN-FR-DGB	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
1.2E-008	6.62	EPS-FAN-FR-DGB SSW-MDP-TM-TRNA	RCI-XHE-XO-ERROR HCS-XHE-XO-ERROR1
1.1E-008	6.40	RCI-XHE-XO-ERROR EPS-DGN-FS-DGB	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
4.2E-009	2.40	RCI-XHE-XO-ERROR SSW-MDP-FS-PUMPB	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
3.0E-009	1.69	SSW-MDP-TM-TRNA HCS-MDP-TM-TRAIN RCI-XHE-XL-START	EPS-DGN-FR-DGB RCI-TDP-FS-TRAIN
2.8E-009	1.60	RCI-XHE-XO-ERROR SSW-XHE-XR-TRNB	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
2.8E-009	1.60	RCI-XHE-XO-ERROR SSW-MOV-CC-F018B	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
2.8E-009	1.60	RCI-XHE-XO-ERROR SSW-MOV-CC-F001B	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
2.8E-009	1.60	RCI-XHE-XO-ERROR SSW-MOV-CC-F006B	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
2.8E-009	1.60	RCI-XHE-XO-ERROR SSW-MOV-CC-F005B	SSW-MDP-TM-TRNA HCS-XHE-XO-ERROR1
2.2E-009	1.28	EPS-FAN-FS-DGB SSW-MDP-TM-TRNA	RCI-XHE-XO-ERROR HCS-XHE-XO-ERROR1
2.0E-009	1.11	EPS-FAN-FR-DGB HCS-MDP-TM-TRAIN RCI-XHE-XL-START	SSW-MDP-TM-TRNA RCI-TDP-FS-TRAIN
1.9E-009	1.07	SSW-MDP-TM-TRNA HCS-MDP-TM-TRAIN RCI-XHE-XL-START	EPS-DGN-FS-DGB RCI-TDP-FS-TRAIN
1.8E-009	1.04	SSW-MDP-TM-TRNA HCS-MDP-TM-TRAIN RCI-XHE-XL-RUN	EPS-DGN-FR-DGB RCI-TDP-FR-TRAIN
1.8E-009	1.04	RCI-TDP-TM-TRAIN EPS-DGN-FR-DGB	SSW-MDP-TM-TRNA HCS-MDP-FS-HPCS
1.8×10^{-7}	**18%**	**Total (all cutsets)[1]**	

1. Total Importance includes all cutsets (including those not shown in this table).

Table 3a. (Continued) Conditional cut sets for the dominant sequences.

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)	
Event Tree: LOOP Sequence 40			
7.0E-008	45.86	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-XHE-XO-ERROR HCS-XHE-XO-ERROR1
1.2E-008	7.71	CRD-XHE-XM-VLVS HCS-MDP-TM-TRAIN RCI-XHE-XL-START	ADS-XHE-XM-MDEPR RCI-TDP-FS-TRAIN
7.3E-009	4.75	CRD-XHE-XM-VLVS HCS-MDP-TM-TRAIN RCI-XHE-XL-RUN	ADS-XHE-XM-MDEPR RCI-TDP-FR-TRAIN
7.2E-009	4.72	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-TDP-TM-TRAIN HCS-MDP-FS-HPCS
6.0E-009	3.93	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-TDP-TM-TRAIN HCS-XHE-XO-ERROR
6.0E-009	3.93	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-TDP-TM-TRAIN HCS-MOV-CC-INJEC
3.6E-009	2.36	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-TDP-TM-TRAIN HCS-MOV-FT-SUCTR
3.5E-009	2.29	CRD-XHE-XM-VLVS HCS-MDP-TM-TRAIN	ADS-XHE-XM-MDEPR RCI-MOV-CC-INJEC
3.5E-009	2.29	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-XHE-XO-ERROR HCS-MDP-TM-TRAIN
3.1E-009	2.02	CRD-XHE-XM-VLVS ADS-XHE-XM-MDEPR	RCI-TDP-TM-TRAIN HCS-MDP-FR-HPCS
2.0E-009	1.32	CRD-XHE-XM-VLVS HCS-MDP-FS-HPCS RCI-XHE-XL-START	ADS-XHE-XM-MDEPR RCI-TDP-FS-TRAIN
1.8E-009	1.17	CRD-XHE-XM-VLVS HCS-MDP-TM-TRAIN RCI-RESTART	ADS-XHE-XM-MDEPR RCI-TDP-FS-RSTRT RCI-XHE-XL-RSTRT
1.7E-009	1.10	CRD-XHE-XM-VLVS HCS-MOV-CC-INJEC RCI-XHE-XL-START	ADS-XHE-XM-MDEPR RCI-TDP-FS-TRAIN
1.7E-009	1.10	CRD-XHE-XM-VLVS RCI-TDP-FS-TRAIN RCI-XHE-XL-START	ADS-XHE-XM-MDEPR HCS-XHE-XO-ERROR
1.5×10^{-7}	**15%**	**Total (all cutsets)[1]**	

1. Total Importance includes all cutsets (including those not shown in this table).

Table 3a. (Continued) Conditional cut sets for the dominant sequences.

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)	
Event Tree: LOOP Sequence 05			
1.6E-008	13.12	RHR-XHE-XM-ERROR SDC-LTERM-NOREC	AIR-XHE-NOREC-2HR
8.0E-009	6.56	RHR-XHE-XM-ERROR SDC-LTERM-NOREC	CVS-XHE-XM-VENT
7.2E-009	5.91	CVS-AOV-CC-AV37 SDC-LTERM-NOREC	RHR-XHE-XM-ERROR
7.2E-009	5.91	CVS-AOV-CC-AV34 SDC-LTERM-NOREC	RHR-XHE-XM-ERROR
7.2E-009	5.91	CVS-AOV-CC-AV36 SDC-LTERM-NOREC	RHR-XHE-XM-ERROR
7.2E-009	5.91	CVS-AOV-CC-AV35 SDC-LTERM-NOREC	RHR-XHE-XM-ERROR
1.7E-009	1.42	RHR-MDP-CF-START SDC-LTERM-NOREC	AIR-XHE-NOREC-2HR
1.2×10^{-7}	**12%**	**Total (all cutsets)[1]**	

1. Total Importance includes all cutsets (including those not shown in this table).

Table 3a. (Continued) Conditional cut sets for the dominant sequences.

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)	
Event Tree: LOOP Sequence 44-39			
1.8E-008	17.27	PPR-SRV-OO-1VLV EPS-DGN-CF-RUN	RCI-TDP-TM-TRAIN
1.5E-008	14.33	EPS-FAN-CF-RUN RCI-TDP-TM-TRAIN	PPR-SRV-OO-1VLV
7.1E-009	7.00	PPR-SRV-OO-1VLV EPS-DGN-CF-START	RCI-TDP-TM-TRAIN
4.9E-009	4.84	PPR-SRV-OO-1VLV RCI-TDP-FS-TRAIN	EPS-DGN-CF-RUN RCI-XHE-XL-START
4.1E-009	4.01	EPS-FAN-CF-RUN RCI-TDP-FS-TRAIN	PPR-SRV-OO-1VLV RCI-XHE-XL-START
3.0E-009	2.98	PPR-SRV-OO-1VLV RCI-TDP-FR-TRAIN	EPS-DGN-CF-RUN RCI-XHE-XL-RUN
2.5E-009	2.47	EPS-FAN-CF-RUN RCI-TDP-FR-TRAIN	PPR-SRV-OO-1VLV RCI-XHE-XL-RUN
2.3E-009	2.26	EPS-FAN-CF-START RCI-TDP-TM-TRAIN	PPR-SRV-OO-1VLV
2.0E-009	1.96	PPR-SRV-OO-1VLV RCI-TDP-FS-TRAIN	EPS-DGN-CF-START RCI-XHE-XL-START
1.5E-009	1.44	PPR-SRV-OO-1VLV RCI-XHE-XM-RCOOL	EPS-DGN-CF-RUN
1.5E-009	1.44	PPR-SRV-OO-1VLV EPS-DGN-CF-RUN	RCI-XHE-XO-ERROR
1.5E-009	1.44	PPR-SRV-OO-1VLV RCI-MOV-CC-INJEC	EPS-DGN-CF-RUN
1.3E-009	1.29	PPR-SRV-OO-1VLV	DCP-BAT-CF-BATT
1.2E-009	1.21	PPR-SRV-OO-1VLV RCI-TDP-FR-TRAIN	EPS-DGN-CF-START RCI-XHE-XL-RUN
1.2E-009	1.19	EPS-FAN-CF-RUN RCI-XHE-XO-ERROR	PPR-SRV-OO-1VLV
1.2E-009	1.19	EPS-FAN-CF-RUN RCI-MOV-CC-INJEC	PPR-SRV-OO-1VLV
1.2E-009	1.19	EPS-FAN-CF-RUN RCI-XHE-XM-RCOOL	PPR-SRV-OO-1VLV
1.0×10^{-7}	**10%**	**Total (all cutsets)[1]**	

1. Total Importance includes all cutsets (including those not shown in this table).

Table 4. Definitions and probabilities for modified and dominant basic events.

Event Name	Description	Probability/ Frequency (per year)	Modified
ADS-SRV-CC-VALV1	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV2	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV3	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV4	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV5	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV6	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV7	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-SRV-CC-VALV8	ADS VALVE FAILS TO OPEN	2.5E-003	
ADS-TSW-FT-DC125	POWER TRANSFER SWITCH FAILS TO TRANSFER	1.5E-003	
ADS-XHE-XM-MDEPR	OPERATOR FAILS TO DEPRESSURIZE THE REACTOR	5.0E-004	
ADS-XHE-XM-STMLN	OPERATOR FAILS TO ALIGN RCIC STEAM LINE FOR D	1.0E-003	
AIR-XHE-NOREC-2HR	OPERATOR FAILS TO RESTORE INSTRUMENT AIR IN	2.0E-003	YES(2)
CCW-XHE-XO-ERROR	OPERATOR FAILS TO MAINTAIN CCW FLOW	1.0E-003	
CRD-XHE-XM-VLVS	OPERATOR FAILS TO ALIGN CRD VALVES FOR ENHANC	1.0E+000	
CVS-AOV-CC-AV34	VENT VALVE FAILS TO OPEN	9.0E-004	
CVS-AOV-CC-AV35	VENT VALVE FAILS TO OPEN	9.0E-004	
CVS-AOV-CC-AV36	VENT VALVE FAILS TO OPEN	9.0E-004	
CVS-AOV-CC-AV37	VENT VALVE FAILS TO OPEN	9.0E-004	
CVS-XHE-XM-VENT	OPERATOR FAILS TO VENT CONTAINMENT	1.0E-003	
DCP-BAT-CF-BATT	COMMON CAUSE FAILURE OF DIVISION 1-3 BATTERIE	4.3E-008	
DCP-BAT-LP-BATTA	DIVISION I BATTERIES FAIL	1.2E-005	
DCP-BAT-LP-BATTB	DIVISION II BATTERIES FAIL	1.2E-005	
DCP-BDC-LP-DI	DIVISION I 125VDC BUS FAILS	4.8E-006	
EPS-DGN-CF-RUN	DIESEL GENERATORS FAIL FROM COMMON CAUSE TO R	4.7E-005	
EPS-DGN-CF-START	DIESEL GENERATORS FAIL FROM COMMON CAUSE TO S	1.9E-005	
EPS-DGN-FR-DGA	DIESEL GENERATOR A FAILS TO RUN	6.3E-003	YES(1)
EPS-DGN-FR-DGB	DIESEL GENERATOR B FAILS TO RUN	6.3E-003	YES(1)
EPS-DGN-FR-DGC	DIESEL GENERATOR C FAILS TO RUN	6.3E-003	YES(1)
EPS-DGN-FS-DGA	DIESEL GENERATOR A FAILS TO START	4.0E-003	
EPS-DGN-FS-DGB	DIESEL GENERATOR B FAILS TO START	4.0E-003	
EPS-DGN-FS-DGC	DIESEL GENERATOR C FAILS TO START	4.0E-003	
EPS-DGN-TM-DGA	DG A IS UNAVAILABLE BECAUSE OF MAINTENANCE	9.0E-003	
EPS-DGN-TM-DGC	DG C IS UNAVAILABLE BECAUSE OF MAINTENANCE	9.0E-003	
EPS-FAN-CF-RUN	DG ROOM VENTILLATION FANS FAILS TO RUN DUE TO	3.9E-005	
EPS-FAN-CF-START	DG ROOM VENTILLATION FANS FAIL TO START DUE T	6.2E-006	
EPS-FAN-FR-DGA	DGA ROOM VENTILLATION FAN FAILS TO RUN	4.1E-003	
EPS-FAN-FR-DGB	DGB ROOM VENTILLATION FANS FAILS TO RUN	4.1E-003	
EPS-FAN-FR-DGC	DGC ROOM VENTILLATION FAN FAILS TO RUN	4.1E-003	
EPS-FAN-FS-DGB	DGB ROOM VENTILLATION FAN FAILS TO START	8.0E-004	
EPS-FAN-TM-DGA	DGA ROOM VENTILLATION FAN FAILS TO START	2.0E-003	
EPS-PND-CF-ALL	DG ROOM VENTILLATION DAMPERS FAIL DUE TO CCF	1.5E-006	
EPS-XHE-XE-DGXTI	OPERATORS FAIL TO CROSS-TIE HPCS DIESEL	1.3E-001	
EPS-XHE-XL-NR01H	OPERATOR FAILS TO RECOVER EMERGENCY DIESEL IN	8.4E-001	
EPS-XHE-XL-NR04H	OPERATOR FAILS TO RECOVER EMERGENCY DIESEL IN	5.0E-001	
EPS-XHE-XL-NR08H	OPERATOR FAILS TO RECOVER EMERGENCY DIESEL IN	2.5E-001	
EPS-XHE-XL-NR30M	OPERATOR FAILS TO RECOVER EMERGENCY DIESEL IN	9.2E-001	
FW2-XHE-XM-ERROR	OPERATOR FAILS TO ALIGN FIREWATER	1.0E-003	

NOTES:
1. Base case values modified to reflect actual diesel generator run times.
2. Base case values modified to reflect short term, long term non-recovery modeling assumptions. (See Appendix D)
3. Values selected to simulate loss of onsite electric power.

Table 4. (Continued) Definitions and probabilities for modified and dominant basic events.

Event Name	Description	Probability/ Frequency (per year)	Modified
HCS-MDP-FR-HPCS	HPCS PUMP FAILS TO RUN	5.2E-004	
HCS-MDP-FS-HPCS	HPCS PUMP FAILS TO START	1.2E-003	
HCS-MDP-TM-TRAIN	HPCI TRAIN IS UNAVAILABLE BECAUSE OF MAINTENA	7.0E-003	
HCS-MOV-CC-INJEC	HPCS INJECTION VALVE FAILS TO OPEN	1.0E-003	
HCS-MOV-FT-SUCTR	HPCS SUCTION TRANSFER FAILS	6.0E-004	
HCS-XHE-XO-ERROR	OPERATOR FAILS TO START/CONTROL HPCS INJECTIO	1.0E-003	
HCS-XHE-XO-ERROR1	OPERATOR FAILS TO START/CONTROL HPCS INJECTIO	1.4E-001	
OEP-XHE-XL-NR01H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 1	2.0E-002	YES(2)
OEP-XHE-XL-NR04H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 4	2.0E-004	YES(2)
OEP-XHE-XL-NR08H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 8	2.0E-004	YES(2)
OEP-XHE-XL-NR30M	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 30	2.0E-002	YES(2)
OPR-XHE-ADSINHIB	OPERATOR FAILS TO INHIBIT ADS AND CONTROL LVL	1.0E-003	
OPR-XHE-NOOVRFIL	OPERATOR FAILS TO CONTROL LEVEL	2.0E-003	
OPR-XHE-XM-ALPI2	OPERATOR FAILS TO ALIGN ALTERNATE LOW PRESSUR	1.0E-003	
PCS-XHE-XL-NOREC	OPERATOR FAILS TO RECOVER PCS DURING ATWS	1.0E+000	
PPR-SRV-CC-SRVS	SAFETY RELIEF VALVES FAIL TO OPEN	2.0E-004	
PPR-SRV-OO-1VLV	ONE SRV FAILS TO CLOSE	3.1E-002	
PPR-SRV-OO-2VLVS	TWO SRVS FAIL TO CLOSE	1.3E-003	
PPR-SRV-OO-3VLVS	THREE OR MORE SRVS FAIL TO CLOSE	2.0E-004	
RCI-MOV-CC-INJEC	RCIC INJECTION VALVE CAUSES FAILURE TO START	1.0E-003	
RCI-RESTART	RESTART OF RCIC IS REQUIRED	8.5E-002	
RCI-TDP-FR-TRAIN	RCIC PUMP FAILS TO RUN GIVEN THAT IT STARTED	4.1E-003	
RCI-TDP-FS-RSTRT	RCIC FAILS TO RESTART GIVEN START AND SHORT-T	1.2E-002	
RCI-TDP-FS-TRAIN	RCIC PUMP FAILS TO START	6.0E-003	
RCI-TDP-TM-TRAIN	RCIC PUMP TRAIN IS UNAVAILABLE BECAUSE OF MAI	1.2E-002	
RCI-XHE-XL-RSTRT	OPERATOR FAILS TO RECOVER RCIC FAILURE TO RES	5.0E-001	
RCI-XHE-XL-RUN	OPERATOR FAILS TO RECOVER RCIC FAILURE TO RUN	5.0E-001	
RCI-XHE-XL-START	OPERATOR FAILS TO RECOVER RCIC FAILURE TO STA	5.6E-001	
RCI-XHE-XM-RCOOL	OPERATOR FAILS TO ESTABLISH ROOM COOLING WITH	1.0E-003	
RCI-XHE-XO-ERROR	OPERATOR FAILS TO START/CONTROL RCIC INJECTIO	1.0E-003	
RHR-MDP-CF-START	RHR PUMPS FAIL FROM COMMON CAUSE TO START	5.4E-005	
RHR-MDP-FR-PUMPA	RHR PUMP A FAILS TO RUN	5.2E-004	
RHR-MDP-FR-PUMPB	RHR PUMP B FAILS TO RUN	5.2E-004	
RHR-MDP-FS-PUMPA	RHR PUMP A FAILS TO START	1.2E-003	
RHR-MDP-FS-PUMPB	RHR PUMP B FAILS TO START	1.2E-003	
RHR-MDP-TM-TRNA	RHR TRAIN A IS UNAVAILABLE BECAUSE OF MAINTEN	7.0E-003	
RHR-MDP-TM-TRNB	RHR TRAIN B IS UNAVAILABLE BECAUSE OF MAINTEN	7.0E-003	
RHR-MOV-CC-F003A	RHR HTX A DISCHARGE MOV F003A FAILS TO OPEN	1.0E-003	
RHR-MOV-CC-F003B	RHR HTX B DISCHARGE MOV F003A FAILS TO OPEN	1.0E-003	
RHR-MOV-OO-BYPSA	RHR LOOP A HEAT EXCHANGER BYPASS VALVE FAILS	1.0E-003	
RHR-MOV-OO-BYPSB	RHR LOOP B HEAT EXCHANGER BYPASS VALVES FAIL	1.0E-003	
RHR-STR-CF-SPOOL	ECCS SUPPRESSION POOL STRAINERS FAIL FROM COM	5.6E-008	
RHR-XHE-XM-ERROR	OPERATOR FAILS TO START/CONTROL RHR	5.0E-004	
RHR-XHE-XR-TRNA	RHR TRAIN A NOT RESTORED AFTER MAINTENANCE	1.0E-003	
RHR-XHE-XR-TRNB	RHR TRAIN B NOT RESTORED AFTER MAINTENANCE	1.0E-003	
RPS-SYS-FC-CRD	CONTROL ROD DRIVE MECHANICAL FAILURE	2.5E-007	

NOTES:
1. Base case values modified to reflect actual diesel generator run times.
2. Base case values modified to reflect short term, long term non-recovery modeling assumptions. (See Appendix D)
3. Values selected to simulate loss of onsite electric power.

Table 4. (Continued) Definitions and probabilities for modified and dominant basic events.

Event Name	Description	Probability/ Frequency (per year)	Modified
RPS-SYS-FC-HCU	HCU COMPONENTS FAIL	1.1E-007	
RPS-SYS-FC-PSOVS	HCU SCRAM PILOT SOVS FAIL	1.7E-006	
RPS-SYS-FC-RELAY	TRIP SYSTEM RELAYS FAIL	3.8E-007	
RRS-CRB-CC-PUMP1	RECIRC PUMP 1 FIELD BREAKER FAILS TO OPEN	1.5E-003	
RRS-CRB-CC-PUMP2	RECIRC PUMP 2 FIELD BREAKER FAILS TO OPEN	1.5E-003	
SDC-LTERM-NOREC	OPERATOR FAILS TO RECOVER SDC IN THE LONG-TER	1.6E-002	
SLC-CKV-CC-F006	SLC INJECTION CHECK VALVE F006 FAILS TO OPEN	1.0E-004	
SLC-CKV-CC-F007	SLC INJECTION CHECK VALVE F007 FAILS TO OPEN	1.0E-004	
SLC-CKV-CC-F222	SLC INJECTION CHECK VALVE F222 FAILS TO OPEN	1.0E-004	
SLC-MDP-TM-TRNB	SLC PUMP TRAIN B IS UNAVAILABLE BECAUSE OF MA	5.0E-003	
SLC-XHE-XM-ERROR	OPERATOR FAILS START/CONTROL SLC	1.0E-003	
SLC-XHE-XR-SLCS	OPERATOR FAILS TO RESTORE SLCS AFTER MAINTENA	1.0E-003	
SSW-MDP-FR-PUMPB	SSW PUMP B FAILS TO RUN	5.2E-004	
SSW-MDP-FS-PUMPA	SSW PUMP A FAILS TO START	1.5E-003	
SSW-MDP-FS-PUMPB	SSW PUMP B FAILS TO START	1.5E-003	
SSW-MDP-TM-TRNA	SSW PUMP A IS UNAVAILABLE BECAUSE OF MAINTENA	2.0E-002	
SSW-MDP-TM-TRNC	SSW PUMP C IS UNAVAILABLE BECAUSE OF MAINTENA	2.0E-002	
SSW-MOV-CC-F001B	SSW PUMP B DISCHARGE MOV F001B FAILS TO OPEN	1.0E-003	
SSW-MOV-CC-F005B	SSW PUMP A BASIN RETURN MOV F005B FAILS TO OP	1.0E-003	
SSW-MOV-CC-F006B	SSW PUMP B RECIRC MOV F006B FAILS TO OPEN	1.0E-003	
SSW-MOV-CC-F014A	RHR HTX SSW SUPPLY VALVE F014A FAILS TO OPEN	1.0E-003	
SSW-MOV-CC-F014B	RHR HTX SSW SUPPLY VALVE F014B FAILS TO OPEN	1.0E-003	
SSW-MOV-CC-F018B	COOLING WATER CONTROL VALVE FAILS TO OPEN	1.0E-003	
SSW-MOV-CC-F068A	RHR HTX SSW OUTLET ISOLATION VLV F068A FAILS	1.0E-003	
SSW-MOV-CC-F068B	RHR HTX SSW OUTLET ISOLATION VLV F068B FAILS	1.0E-003	
SSW-XHE-XR-TRNB	SSW TRAIN B NOT RESTORED AFTER MAINTENANCE	1.0E-003	
IE-HCS-V	**HPCS ISOLATION VALVE 13-21 O**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-LCS-V	**LPCS ISOLATION VALVE 13-21 O**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-LLOCA	**LARGE LOCA INITIATOR**	**3.0E-005 +0.0E+000 FALSE**	**YES(3)**
IE-LOOP	**LOSS OF OFFSITE POWER**	**3.3E-002 1.0E+000 TRUE**	**YES(3)**
IE-MLOCA	**MEDIUM LOCA INITIATOR**	**4.0E-005 +0.0E+000 FALSE**	**YES(3)**
IE-RCI-V	**RCIC ISOLATION VALVE 13-21 O**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-RHR-V-A	**LPCI LOOP A ISOLATION VALVE**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-RHR-V-B	**LPCI LOOP B ISOLATION VALVE**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-RHR-V-C	**LPCI LOOP C ISOLATION VALVE**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-RHR-V-S	**SHUTDOWN COOLING ISOLATION V**	**5.7E-007 +0.0E+000 FALSE**	**YES(3)**
IE-SLOCA	**SMALL LOCA INITIATING EVENT**	**4.0E-004 +0.0E+000 FALSE**	**YES(3)**
IE-TDCB	**LOSS OF VITAL DC BUS**	**2.5E-003 +0.0E+000 FALSE**	**YES(3)**
IE-TRANS	**TRANSIENT INITIATOR**	**8.0E-001 +0.0E+000 FALSE**	**YES(3)**
IE-TSWS	**TOTAL LOSS OF SERVICE WATER**	**4.0E-004 +0.0E+000 FALSE**	**YES(3)**
ZV-LOOP-EW-LAMBDA	**EXTREME WEATHER RELATED LOSS**	**2.3E-003 +0.0E+000**	**YES(3)**
ZV-LOOP-GR-LAMBDA	**GRID RELATED LOSS OF OFFSITE**	**1.7E-002 +0.0E+000**	**YES(3)**
ZV-LOOP-PC-LAMBDA	**PLANT CENTERED LOSS OF OFFSI**	**2.4E-003 +0.0E+000**	**YES(3)**
ZV-LOOP-SC-LAMBDA	**SWITCHYARD CENTERED LOSS OF**	**8.7E-003 1.0E+000**	**YES(3)**
ZV-LOOP-SW-LAMBDA	**SEVERE WEATHER RELATED LOSS**	**3.0E-003 +0.0E+000**	**YES(3)**

NOTES:
1. Base case values modified to reflect actual diesel generator run times.
2. Base case values modified to reflect short term, long term non-recovery modeling assumptions. (See Appendix D)
3. Values selected to simulate loss of onsite electric power.

Appendix A

Sequence of Key Events

April 24, 2003

09:48:34	500 kV Breaker J5204 Disconnected J5205 closes (due to wind) causing a line-to-ground fault.
09:48:34	ST21 Lockout Trip, Breakers J5208 and J1652 Open, ST21 Lost. Breakers J2425, J2420 Open. Franklin 500 kV Line De-energized. Breakers J2240, 2244 Open. Baxter-Wilson 500 kV Line De-energized. West Bus Lockout. Breakers J5228, J5240, J5216 Open.
09:48:34	Load rejection relay actuates, Turbine Control Valve Fast Closure, Automatic Reactor Protection System trip.
09:48:34	Condensate Booster Pump C, Condensate Pumps B and C trip.
09:48:37	Division II EDG start sequence initiated.
09:48:37	Division III EDG start sequence initiated.
09:48:38	Turbine trip, Turbine stop valve closure.
09:48:41	Unit 2 Instrument Air Compressor trip.
09:48:42	Safety/Relief Valve auto actuation (2 S/RVs open for approximately 1 minute and begin to cycle to maintain pressure control)
09:48:46	Condensate Booster Pump A trip.
09:48:50	Condensate Booster Pump B trip.
09:48:53	Manual Reactor Scram, Mode switch placed in Shutdown Mode.
09:49:15	Main Steam Line Isolation Valves close.
09:49:20	Condensate Pump A trip.
09:49:47	Reactor Feedwater Pumps A,B trip.
09:49:47	Main Generator lockout relay actuated (Volts/Hertz ratio)
09:49:48	Main Generator output breaker opens. Generator is off-line and East 500 kV bus de-energized.
09:49:49	Breaker J2425 auto-closes. Franklin 500 kV line re-energizes.
09:49:51	Breaker J2240 auto-closes. Baxter-Wilson 500 kV line re-energizes.
09:49:53	Division I EDG start sequence initiated.
09:50:05	Service Air and Instrument Air auto cross-connect at ~90 psig.

09:56:02	RPV Level 2 reached.
09:56:07	High Pressure Core Spray (HPCS) and Reactor Core Isolation Cooling (RCIC) systems auto-start.
09:58:40	HPCS pump secured by control room operator.
09:58:xx	Control room operators establish and maintain RPV pressure and level via manual operation of S/RVs and RCIC.
09:59:41	Unit 1 Instrument Air Compressor auto-start.
10:18:29	Unit 1 Instrument Air Compressor trip (loss of seal air pressure).
10:20:51	Control room operators start Suppression Pool Cooling using Residual Heat Removal (RHR) System A.
10:25:28	Control room operators start Suppression Pool Cooling using RHR System B.
10:25:xx	Unit 1 Instrument Air Compressor restarted and secured several times in attempt to provide temporary control air. Instrument air header pressure not restored.
10:58:xx	Offsite Power restored to ST21.
11:08:xx	Abnormal sounds and vibration reported by eyewitnesses near the Unit 1 Instrument Air Compressor.
11:45:xx	Unit 2 Instrument Air Compressor started by manually adjusting fittings and regulators.
11:50:xx	Attempts to restore Unit 1 Instrument Air Compressor suspended.
11:51:xx	Unit 2 Instrument Air Compressor restores header air pressure.
14:38:xx	Condensate Pump A restarted.
14:53:xx	Power restored to Division III ESF Bus from offsite power. Division III EDG secured.
15:30:xx	Condensate Booster Pump C restarted.
15:37:xx	Power restored to Division II ESF Bus from offsite power. Division II EDG secured.
16:00:xx	Power restored to Division I ESF Bus from offsite power. Division I EDG secured.
17:00:xx	Feedwater Control System placed on start-up water level control.
22:02:xx	Spent Fuel Pool Cooling restored.
23:25:xx	Main Steam Isolation Valves re-opened. Unable to recover Main Condenser due to inoperable (tagged out) mechanical vacuum pump.

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05:15:xx	RHR System B started in Shutdown Cooling Mode.

06:35:00 Reactor plant in Mode 4. Reactor plant temperature < 200 ˚F.

Appendix B

Event Tree Model

Showing Dominant Sequences

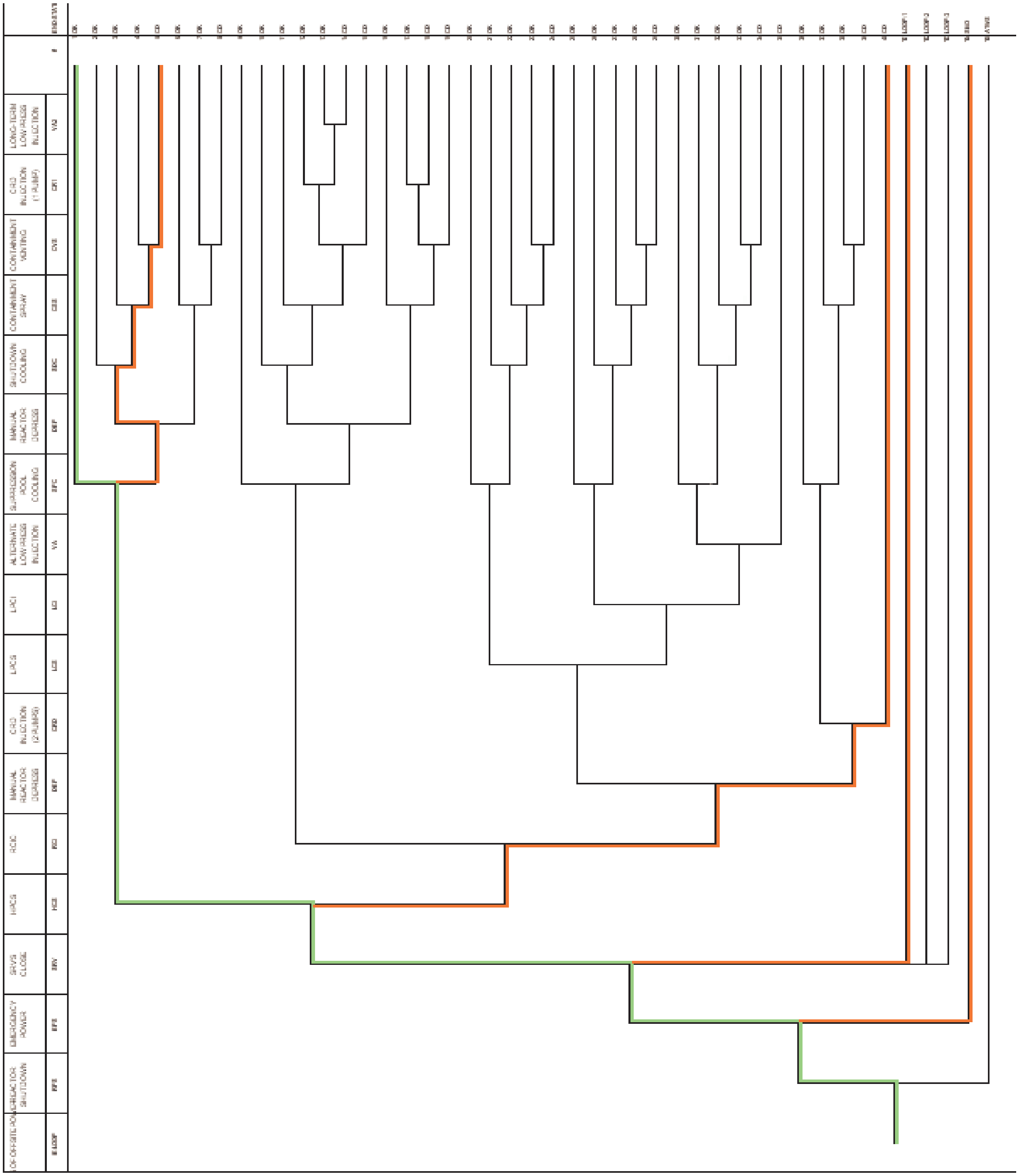


Figure B-1 - Grand Gulf 1 Loss of Offsite Power Event Tree

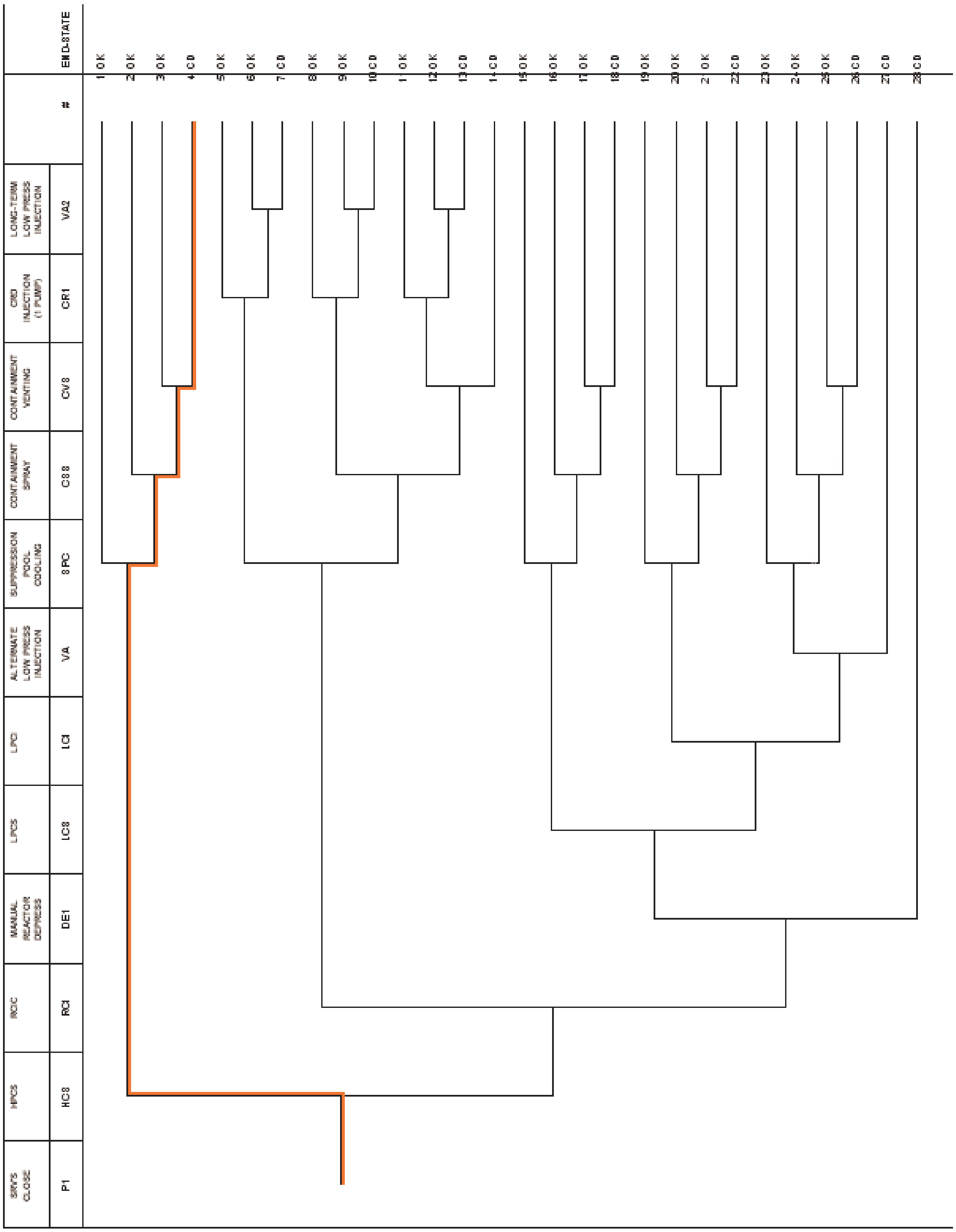


Figure B-2 - Grand Gulf 1 Open Relief Valve Event Tree

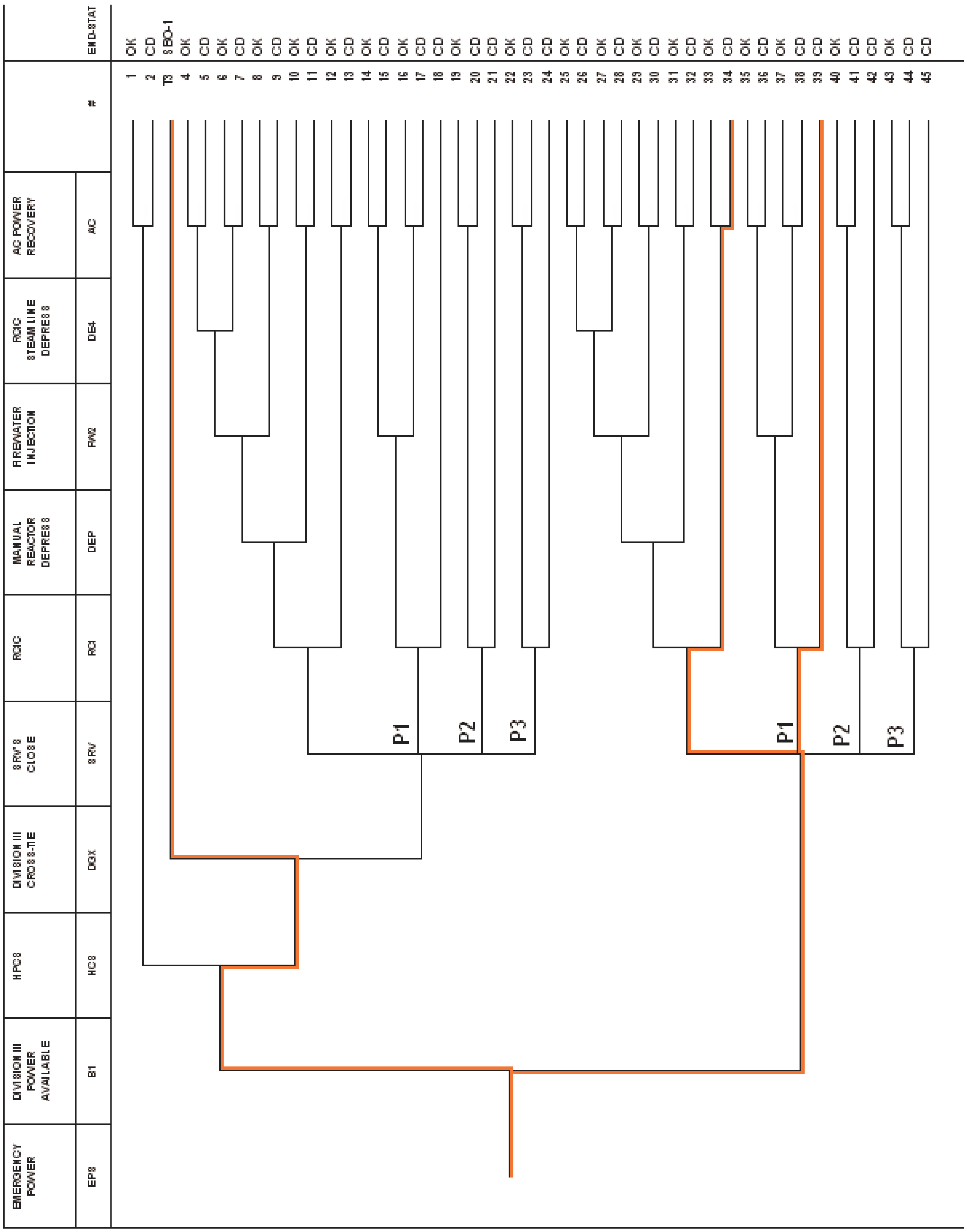


Figure B-3 - Grand Gulf 1 Station Blackout Event Tree

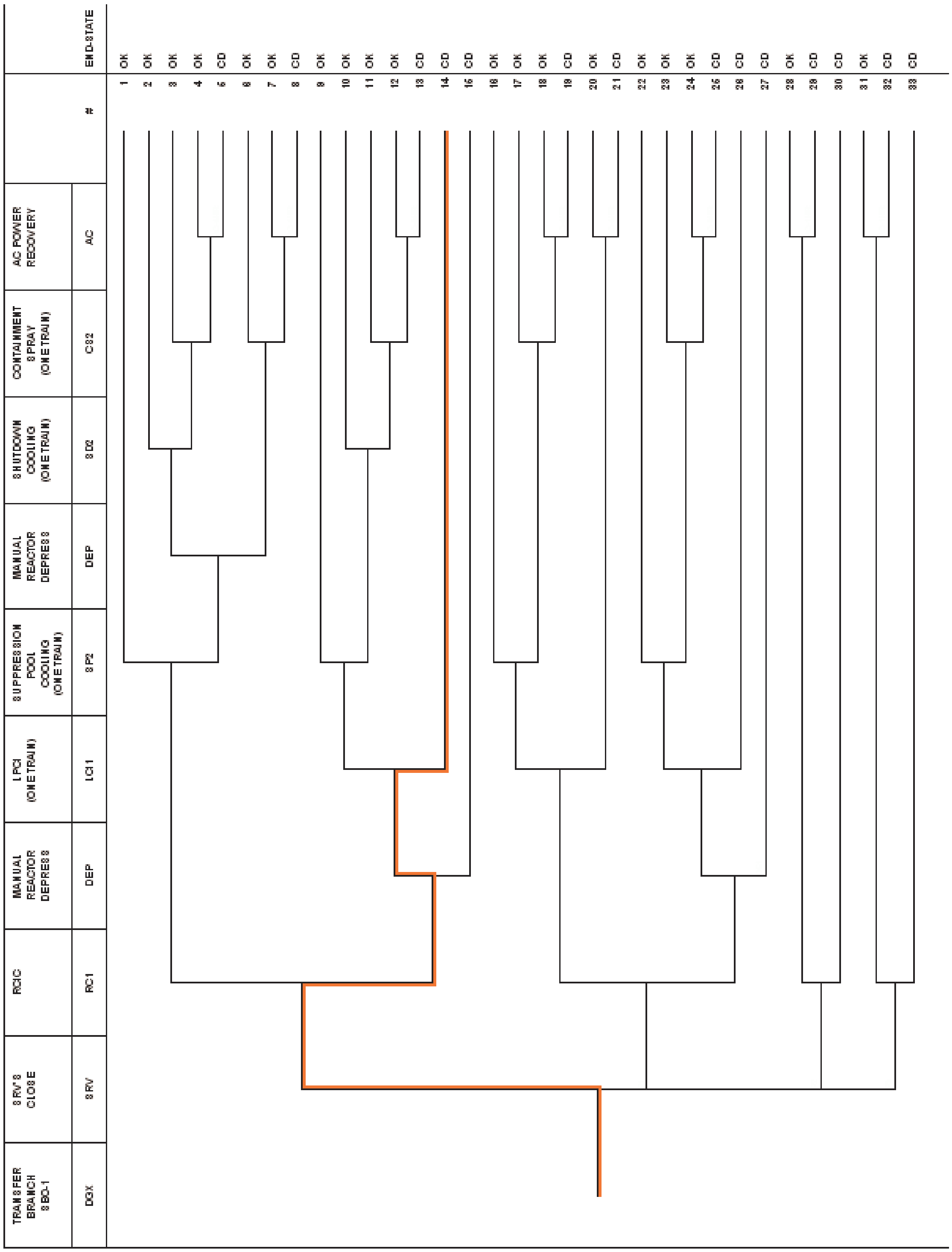


Figure B-4 - Grand Gulf 1 Station Blackout Event Tree

Appendix C

Fault Tree Models

Showing Changes

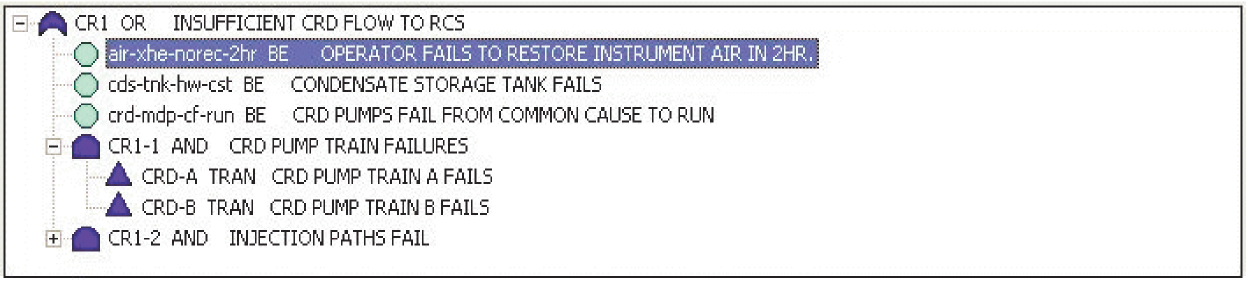


Figure C-1
Modifications to the Base Case CR1 Fault Tree

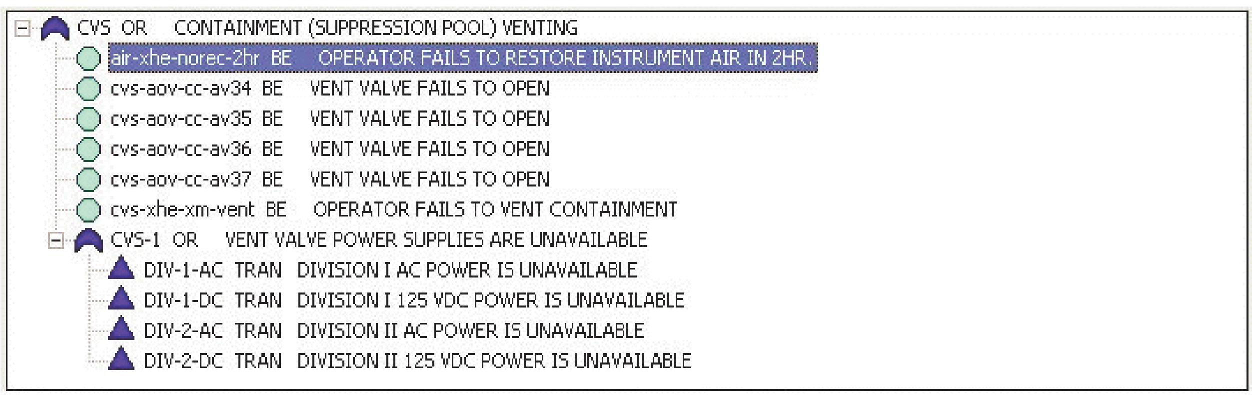
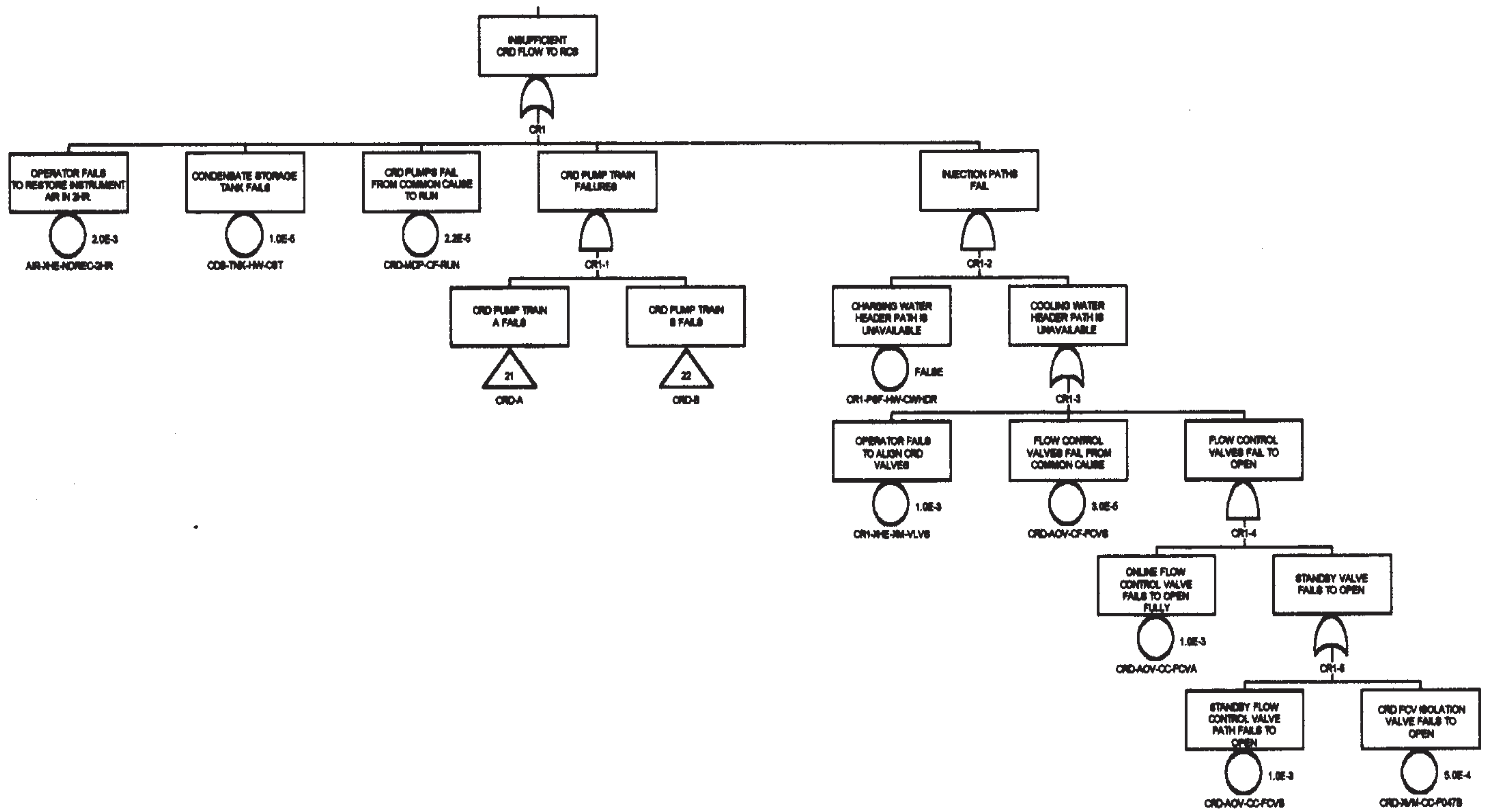
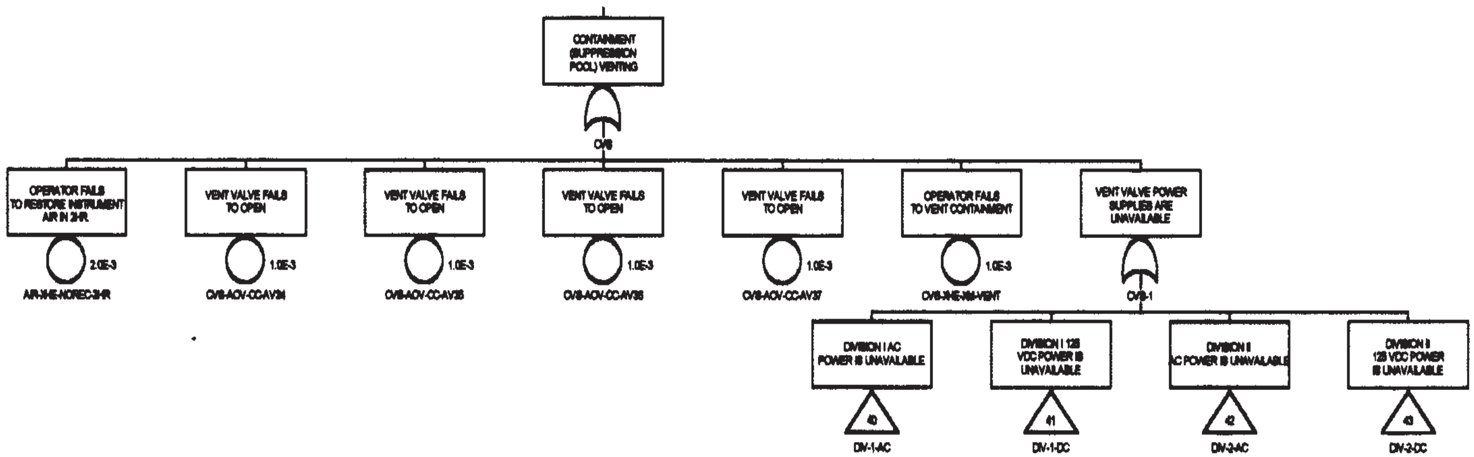


Figure C-2
Modifications to the Base Case CVS Fault Tree



CR1 - GRAND GULF CONTROL ROD DRIVE SYSTEM FAULT TREE 2004/11/04 Page 19



CVS - GRAND GULF SUPRESSION POOL VENT SYSTEM FAULT TREE 2004/11/04 Page 28

Appendix D

Human Reliability Analysis

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Grand Gulf Unit 1 Event Name: **AIR-XHE-NOREC-2HR**

Task Error Description: Operator fails to recover Instrument Air to allow Containment Venting and enhanced CRD flow over the long term following the success of HPCS and RCIC but failure of Suppression Pool Cooling mode of RHR..

Does this task contain a significant amount of diagnosis activity ? YES ✔ NO ____ .

If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0a	Indications on Instrument Air system status exist in the Control Room. The diagnosis of inadequate air pressure would take place after verifying that other ESF features are operating. Suppression pool cooling would not be entered until pool temperatures reached specific limits.
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1 ✓	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	Failure of Suppression Pool Cooling mode of RHR would be the first significant ESF failure.
	High	2	
	Nominal	1 ✓	
3.Complexity	Highly	5	Diagnosis and restoration, or crosstie of Air Compressors is clearly an operation that is done during maintenance activities.
	Moderately	2	
	Nominal	1 ✓	
4. Experience /Training	Low	10	Diagnosis and restoration, or crosstie of Air Compressors is clearly an operation that is done during maintenance activities.
	Nominal	1 ✓	
	High	0.5	
5. Procedures	Not available	50	Diagnosis and restoration, or crosstie of Air Compressors is clearly an operation that is done during maintenance activities.
	Available, but poor	5	
	Nominal	1 ✓	
	Diagnostic/symptom oriented	0.5	
6.Ergonomics	Missing/Misleading	50	Control room indication and alarms exist.
	Poor	10	
	Nominal	1 ✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0a	
	Degraded Fitness	5	
	Nominal	1 ✓	
8. Work Processes	Poor	2	
	Nominal	1 ✓	
	Good	0.5	

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in column
1. Available Time	Inadequate	1.0a	Successful operation of HPCS and RCIC provides several hours to carry out the recovery - as compared to situation where they both fail early.
	Time available ≈ time required	10	
	Nominal	1 ✓	
	Available > 5x time required	0.1	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	This would not be a normal or routine restoration of Instrument Air.
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	Diagnosis and restoration, or crosstie of Air Compressors is clearly an operation that is done during maintenance activities.
	Moderately	2	
	Nominal	1 ✔	
4. Experience/ Training	Low	3	Diagnosis and restoration, or crosstie of Air Compressors is clearly an operation that is done during maintenance activities.
	Nominal	1✔	
	High	0.5	
5. Procedures	Not available	50	Diagnosis and restoration, or crosstie of Air Compressors is clearly an operation that is done during maintenance activities.
	Available, but poor	5	
	Nominal	1✔	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✔	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0a	
	Degraded Fitness	5	
	Nominal	1✔	
8. Work Processes	Poor	2	Pre-positioned equipment (fittings and hoses) existed to facilitate cross-connection.
	Nominal	1	
	Good	0.5 ✔	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x 0.1	x 1.0	x 1.0	x 1.0	x 1.0	x 1.0	x 1.0	x 1.0	1.0E-3

Action	1.0E-3	x 1.0	x 2.0	x 1.0	x 1.0	x 1.0	x 1.0	x 1.0	x 0.5	1.0E-3
Total										2.0E-3

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd error in the sequence, then the dependency is at least moderate. If this error is the 4th error in the sequence, then the dependency is at least high. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6	s	d	nc	a	low	
7	d	s	c	–	moderate	
8	d	s	nc	na	low	
9	d	s	nc	a	low	
10	d	d	c	–	moderate	
11	d	d	nc	na	low	
12	d	d	nc	a	low	
13 ✔					zero	

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
✔For Zero Dependence the probability of failure = P

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Grand Gulf Unit 1 Event Names: **ACP-XHE-NOREC-30M, OEP-XHE-NOREC-1H**
Task Error Description: Operator fails to recover AC Power to de-energized plant buses given that power is available on offsite grid.

Does this task contain a significant amount of diagnosis activity ? YES ___ NO ✔
.Condition of de-energized plant buses is obvious.

If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0a	
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1	
4. Experience/ Training	Low	10	
	Nominal	1	
	High	0.5	
5. Procedures	Not available	50	
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0a	
	Degraded Fitness	5	
	Nominal	1	
8. Work Processes	Poor	2	
	Nominal	1	
	Good	0.5	

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0a	This HEP is for scenarios involving Station Blackout with stuck open S/RVs. In such scenarios core damage can occur in the 30min - 1 hr time frame. Hence the time available is nominally the required time.
	Time available ≈ time required	10 ✓	
	Nominal	1	
	Available > 5x time required	0.1	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	Given local blackout of plant buses stress levels would be higher than nominal.
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Moderately	2	
	Nominal	1 ✔	
4. Experience/ Training	Low	3	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Nominal	1✔	
	High	0.5	
5. Procedures	Not available	50	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Available, but poor	5	
	Nominal	1✔	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✔	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0a	
	Degraded Fitness	5	
	Nominal	1✔	
8. Work Processes	Poor	2	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Nominal	1 ✔	
	Good	0.5	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.										N/A
Action	1.0E-3	x 10	x 2.0	x 1.0	x 1.0	x 1.0	x 1.0	x 1.0	x 0.5	2.0E-2
Total										2.0E-2

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.
Recovery of electrical power on plant buses would be first task.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd error in the sequence, then the dependency is at least moderate. If this error is the 4th error in the sequence, then the dependency is at least high. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6	s	d	nc	a	low	
7	d	s	c	–	moderate	
8	d	s	nc	na	low	
9	d	s	nc	a	low	
10	d	d	c	–	moderate	
11	d	d	nc	na	low	
12	d	d	nc	a	low	
13 ✔					zero	

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
✔For Zero Dependence the probability of failure = P

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: Grand Gulf Unit 1 Event Names: **OEP-XHE-NOREC-2H, OEP-XHE-NOREC-4H, OEP-XHE-NOREC-8H, OEP-XHE-NOREC-10H, OEP-XHE-NOREC-12H** Task Error Description: Operator fails to recover AC Power over the long term to de-energized plant buses given that power is available on offsite grid.

Does this task contain a significant amount of diagnosis activity ? YES NO ✔
Condition of de-energized plant buses is obvious.

If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0a	
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1	
4. Experience/ Training	Low	10	
	Nominal	1	
	High	0.5	
5. Procedures	Not available	50	
	Available, but poor	5	
	Nominal	1	
	Diagnostic/symptom oriented	0.5	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0a	
	Degraded Fitness	5	
	Nominal	1	
8. Work Processes	Poor	2	
	Nominal	1	
	Good	0.5	

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0a	The specific scenarios involved for these HEPs are failures to restore power in time to prevent suppression pool failure due to lack of cooling. The time frame for suppression pool failure is assumed much greater than 2 hours.
	Time available ≈ time required	10	
	Nominal	1	
	Available > 5x time required	0.1 ✓	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	Given local blackout of plant buses stress levels would be higher than nominal.
	High	2 ✓	
	Nominal	1	
3. Complexity	Highly	5	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Moderately	2	
	Nominal	1 ✔	
4. Experience/ Training	Low	3	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Nominal	1✔	
	High	0.5	
5. Procedures	Not available	50	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Available, but poor	5	
	Nominal	1✔	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✔	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0a	
	Degraded Fitness	5	
	Nominal	1✔	
8. Work Processes	Poor	2	Restoration of in-house loads from offsite sources would be covered by standard operating procedures.
	Nominal	1	
	Good	0.5 ✔	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.										N/A
Action	1.0E-3	x 0.1	x 2.0	x 2.0	x 1.0	x 1.0	x 1.0	x 1.0	x 0.5	2.0E-4
Total										2.0E-4

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.
Recovery of electrical power on plant buses would be first task.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd error in the sequence, then the dependency is at least moderate. If this error is the 4th error in the sequence, then the dependency is at least high. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6	s	d	nc	a	low	
7	d	s	c	–	moderate	
8	d	s	nc	na	low	
9	d	s	nc	a	low	
10	d	d	c	–	moderate	
11	d	d	nc	na	low	
12	d	d	nc	a	low	
13 ✔					zero	

Using P = Task Failure Probability Without Formal Dependence (calculated on page 2):

	For Complete Dependence the probability of failure	= 1.0
	For High Dependence the probability of failure	= (1 + P)/2
	For Moderate Dependence the probability of failure	= (1 +6P)/7
	For Low Dependence the probability of failure	= (1 + 19P)/20
✔	For Zero Dependence the probability of failure	= P

Appendix E

Resolution of Licensee Review Comments on Draft Version

Comments on Preliminary Precursor Analysis
Automatic Reactor Scram Due to Loss of Offsite Power With
Condenser Vacuum Pump Inoperable and
Subsequent Failure of Instrument Air

It is estimated that incorporation of the following comments would result in at least a 2.6E-07 reduction in the point estimate CCDP. (The 2.6E-07 is from removal of the contribution from sequences LOOP 41-04 and LOOP 05. Incorporation of other comments would also reduce the remaining CCDP.) The overall point estimate CCDP would be less than 7.4E-07

7. Event Summary, 2nd paragraph--Bus undervoltage on the Division I, II and III ESF buses was caused by the loss power from both ST21 and ST 1 I. The loss of ST21caused undervoltage on the Division II and I I I ESF buses. The Division I bus, which was connected to ST 11, was carried for a short period of time by the plant generator until J5232 opened.

   Response: This does not effect the results or conclusions of the analysis. No changes are incorporated.

8. Event Summary, 4th paragraph-Instrument Air is not required for fire water makeup to the RPV since there is a motor operated bypass valve which can be opened (manually, if necessary) to supply firewater to the auxiliary building. Also, firewater and CRD are considered level control systems, not decay heat removal systems.

   Response: The subject paragraph was revised to note that RPV makeup using Firewater can be accomplished without availability of Instrument Air. This does not change the results or conclusions of the analysis.

9. Analysis Results, Dominant Sequences, 2nd paragraph (sequence LOOP 41 -04)-This sequence is not a realistic depiction of the GGNS response. It includes a dependency between containment heat removal and continued operation of ECCS pumps that does not exist. The HPCS pump (as well as the LPCI and LPCS pumps) can pump saturated water and GGNS has concluded that the HPCS system will not fail as a result of containment failure.

   Response: The assumed ability to continuously recirculate saturated water from the suppression pool to the RPV *following containment failure* and maintain core cooling has not been conclusively demonstrated. No changes were made to the analysis.

10. Analysis Results, Dominant Sequences, 4th paragraph (sequence LOOP 40)-The list of important system and component failures is not consistent with the event tree sequence. The event tree sequence includes failure of depressurization and CRD and it does not include failure of containment spray and containment venting. Note also that GGNS does not consider that CRD can be successful unless some other high pressure system has controlled level for approximately 5 hours.

Response: The text description has been modified as suggested. The modeling change suggested by the licensee, however, will not reduce the estimated ASP CCDP.

11. Analysis Results, Dominant Sequences, 5th paragraph (sequence LOOP 5)-See comment 3 above. This sequence also includes a non-realistic dependency between containment heat removal and continued operation of HPCS and is not applicable to GGNS.

    Response: The assumed ability to continuously recirculate saturated water from the suppression pool to the RPV *following containment failure* and maintain core cooling has not been conclusively demonstrated. No changes were made to the analysis.

12. Modeling Assumptions, Analysis Type, 3rd paragraph-At GGNS any or all of the 3 ESF buses can be connected to any combination (even, only one) of the three ESF transformers. Note also, that once power was restored to the East bus no operator actions were required to restore power to the ESF 11 transformer. In addition the ESF 12 transformer (powered for 115 kv Port Gibson line) was never lost. So with this set of circumstances there would only be operator actions to transfer the ESF buses to either ESF 11 or 12. This is a very simple manipulation (i.e., one switch for each ESF bus) that can be performed in the control room.

    Response: The ASP analysis process did consider this simple operator recovery action, but also considered the possibility that the operator s failed to accomplish the recovery. This does not effect the results or conclusions of the analysis. No changes incorporated.

13. Modeling Assumptions, Analysis Type, 4th paragraph-This states that mission run times have been adjusted consistent with the "time it took to re-energize the ESF buses. Later in the Key modeling assumptions, it is stated that the diesel generator fail to run and common cause failure to run probabilities were adjusted to reflect the run time of the first diesel (5.07 hrs). The statement in the 4th paragraph implies that it "takes" 5.07 hours to re-energize the ESF buses, while the actual time to re-energize a bus is much less than that. This should be revised to state the mission run times were adjusted to be consistent with actual diesel generator run times for the event.

    Response: The ASP analysis was carried out consistent with standard NRC practice for performing such analyses. No changes are incorporated.

14. Modeling Assumptions, Key Modeling Assumptions, 5th bullet, (b)-While it is true that there are air operated valves associated with the fire water RPV makeup, there are also motor operated valves, which can be opened manually, that bypass the air operated valves. Procedures for fire water makeup note that the bypass valves (both remote operation and local manual operation) may have to be utilized.

    Response: This does not effect the results or conclusions of the analysis. No changes are incorporated.

15. Modeling Assumptions, Key Modeling Assumptions, 5th bullet, (c)-This is slightly misleading. Instrument air provides air to the S/RVs for their opening. If air is lost, then it is necessary in the long term to connect bottled air to ensure continued operation of the ADS valves. All of

the S/RVs have accumulators that will allow a number of valve cycles. The ADS S/RVs have, in addition, larger receiver tanks that allow more valve cycles for the ADS valves. Thus, the S/RVs have adequate air to operate for a period of time without the bottles connected.

Response: This does not effect the results or conclusions of the analysis. No changes are incorporated.

16. Modeling Assumptions, Key Modeling Assumptions, 5th bullet, (f) -Note that the instrument air/service air compressors are cooled by turbine building cooling water (TBCW). Note also that instrument air compressor cooling can be cross-tied from TBCW to standby service water B (SSW B).

    Response: This does not effect the results or conclusions of the analysis. No changes are incorporated.

17. Modeling Assumptions, Basic Event Probability Changes, 2nd paragraph (**OEP-XHE-XL-NR30M** & **OEP-XHE-XL-NRO1H** and associated Appendix D worksheet)-This paragraph indicates that the time required to reconnect offsite power to a bus (assuming a ESF bus) is on the order of the available time. This is not true for a station blackout condition. With a dead bus (i.e., diesels failed to start or load) the only action required is to close one switch in the control room for each ESF bus. The action time for this is seconds or a couple of minutes at most. Therefore, the multiplier utilized in Appendix D for Available Time should be at most 0.1 (>5x time required) instead of a multiplier of 10. This would change the probability for these events to 2E-04 instead of 2E-02.

    Response: The base events noted above *do not appear in any of the dominant cutsets* and do not effect the results or conclusions of the analysis. No changes are incorporated.

18. Modeling Assumptions, Basic Event Probability Changes, 2nd paragraph (OEP-XHE-XLNR04H, OEP-XHE-XL-NR08H, and OEP-XHE-XL-NR1 OH and associated Appendix D worksheet)-Same basic comment as comment number 11 above. In this case the multiplier for Available Time should be 0.01 instead of 0.1. This would result in a probability for these events of 2E-05 instead of 2E-04.

    Response: The base events noted above *do not appear in any of the dominant cutsets* and do not effect the results or conclusions of the analysis. No changes are incorporated.

19. Table 3a., Minimum Cut Sets for LOOP Sequence 41-04-As indicated in comment 3 above, this sequence includes a non-realistic dependency between containment heat removal and continued operation of HPCS and is not applicable to GGNS.

    Response: The assumed ability to continuously recirculate saturated water from the suppression pool to the RPV *following containment failure* and maintain core cooling has not been conclusively demonstrated. No changes were made to the analysis.

20. Table 3a., Minimum Cut Sets for LOOP Sequence 44-03-14-These cut sets do not include credit for recovery of offsite power. Credit for recovery of off site power is appropriate since

offsite power recovery to either the Division I or II bus would make other mitigating equipment available. This appears to be true for all of the displayed cut sets. Most of the LCII (one train of low pressure coolant injection) failures appear to be the result of SSW failures. It should be noted that none of the LPCI or LPCS pumps have a direct dependency on SSW. The LPCS pump will fail at approximately 10 to 12 hours due to lack of room cooling although the HPCS DG cross-tie procedure does not allow the use of the LPCS pump if the HPCS DG has been cross-tied to the Div 1 ESF bus. LPCI A and B will automatically switch to containment spray mode on high containment pressure (-9 psig) and there is not a procedure to bypass the automatic realignment. This will occur in approximately 6 to 8 hours if SSW or venting is not available for containment cooling. LPCI C should be able to continue to run even if the containment fails. The bottom line for this sequence is unless there is a failure to start of the low pressure pump for the selected division, there is significant time available to recover offsite.

Response: LOOP Sequence 44-03-14, which is a sequence transferred from the LOOP event tree to the SBO event tree (upon failure on the onsite power system). The 44-03-14 sequence does not need to consider offsite power recover *because Division III power is available* and is successfully cross-connected. The basic events which are found in the dominant sequence cutsets (Table 3a) do not involve unavailability of electric power, they involve equipment unavailability due to test/maintenance, common cause failures, and human errors. No changes were made to the analysis.

21. Table 3a., Minimum Cut Sets for LOOP Sequence 05- As indicated in comment 5 above, this sequence includes a non-realistic dependency between containment heat removal and continued operation of HPCS and is not applicable to GGNS.

    Response: The assumed ability to continuously recirculate saturated water from the suppression pool to the RPV *following containment failure* and maintain core cooling has not been conclusively demonstrated. No changes were made to the analysis.

22. Table 3a., Minimum Cut Sets for LOOP Sequence 44-39-Shouldn't there be recovery of offsite power events in these cutsets? Even with a stuck open relief valve, no HPCS and no RCIC there is approximately 30 minutes available to recover offsite power. More time is available for the RCIC fail to run events.

    Response: The ASP model presumes that with: (a) a loss of offsite power, (b) the failure of all onsite power sources (which incapacitates: HPCS, LPCI, and CRD), (c) the failure of the steam driven RCIC, *and (d) a stuck open S/RV*, that there is insufficient time for offsite power recovery. No analysis has been provided demonstrating that this scenario can be recovered in time. No changes were made to the analysis.

23. Table 3a., Minimum Cut Sets for LOOP Sequence 44-39-Several of the cut sets include a failure of operator to establish room cooling event (RCI-XHE-XM-RCOOL). This is not a failure at GGNS. RCIC does not require room cooling for continued operation for the PRA mission time.

Response: The basic event **RCI-XHE-XM-RCOOL** appears in two dominant sequence cutsets which respectively contribute to: 1.44% and 1.19% of a 10% contributor to CCDP. No analysis has been provided demonstrating the ability of the RCIC to operate without room cooling for specific periods of time. No changes were made to the analysis.

24. Appendix A, April 24, 2003, 09:49:48-East 500 kV line should be East 500 kV bus.

Response: The text has been corrected as suggested.